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From the Editors

The collection of papers presented in this issue of the journal can be read to some extent as representing a macro and micro view in natural history studies. The first two papers present a wider perspective, albeit with different aims. Mo's report of a survey of herpetofauna aims to increase the knowledge and understanding of that range of fauna in a constructed environment with an urban landscape. While also taking in a relatively large area, Murphy's study looks to highlight the diversity of marine fauna within a single locale.

The papers by Saunders and Bilney and Bilney, on the other hand, have a more narrow view, in that they both concentrate attention on an interesting aspect of a single species. Such diversity in the pages of *The Victorian Naturalist* should be recognised as the journal's natural course.

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Front cover: *Hydatina physis*, a gastropod found on Shelly Beach, Port Macquarie. Photo Michael Murphy. (see p. 73).

Back cover: Dairy Creek, Lime Kiln Bay Wetland, south Sydney. Photo Oatley Flora and Fauna Conservation Society. (see p. 92).

Herpetofaunal community of the constructed Lime Kiln Bay Wetland, south Sydney, New South Wales

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Abstract

The Lime Kiln Bay Wetland in south Sydney was constructed between 1999 and 2001. This paper provides the first comprehensive description of the herpetofaunal assemblage at the site from observations made between 2006 and 2014. Twenty-three species were detected: six frogs (Hylidae, Limnodynastidae, Myobatrachidae), one freshwater turtle (Cheluidae), 12 lizards (Agamidae, Carphodactylidae, Scincidae, Varanidae) and four snakes (Colubridae, Elapidae, Pythonidae). (*The Victorian Naturalist* **132** (3) 2015, 64–72)

Keywords: constructed wetland, frog, reptile, species assemblage, urban ecology

Introduction

The Oatley Bushland Corridor is an important stretch of remnant habitat in the St George area of southern Sydney (Waterhouse 1997), along with the Wolli Creek Valley and Rockdale Wetland Corridor. It supports a broad range of habitats, including two endangered ecological communities (Swamp Sclerophyll Forest on coastal floodplain, and Swamp Oak Floodplain Forest). A key feature of the area is the constructed Lime Kiln Bay Wetland, restored as part of Hurstville City Council's rehabilitation of recreational spaces (Bavor *et al.* 1995). A comprehensive fauna survey of the Oatley bushland corridor is lacking, although there have been efforts to document bird assemblages (Fairley *et al.* 2013; B Groves and J Cockayne unpubl. data). Further information is limited to consultant reports (e.g. White 2010a) and website postings (Oatley Flora and Fauna Conservation Society (OFF) 2014).

Studies that provide an inventory of fauna for a given land tenure contribute much toward recognising local ecological values. Knowledge of species present and their habitat requirements is a key resource for informing management decisions (Murphy and Murphy 2011), especially for bushland remnants. Inventories are also useful for detecting biodiversity changes over time, as well as evaluating the metapopulation status of threatened species (Val *et al.* 2012).

This paper provides the first comprehensive description of the herpetofaunal assemblage in the Lime Kiln Bay Wetland. Information for this inventory was generated by casual observations between 2006 and 2014, and compares the frog and reptile assemblages of the study area with those of the Wolli Creek Valley and Rockdale Wetland Corridor.

Methods

Study area

The Lime Kiln Bay Wetland is built on one of the last natural floodplains in the Georges River catchment (Bavor *et al.* 1995), nestled between the suburbs of Oatley, Mortdale and Peakhurst (Fig. 1). Remnant native vegetation is present; however, there has been an extensive history of clearing. The soil types are mostly from the Hawkesbury Sandstone series.

The wetland area includes three main ponds, which cover approximately 4 ha, flanked by a further 24 ha of remnant vegetation. The banks are dominated by Swamp Oak *Casuarina glauca*, Narrow-leaved Paperbark *Melaleuca linariifolia* and Prickly Paperbark *M. styphelioides*. Spiny-headed Matrush *Lomandra longifolia* and other ground cover species have been planted extensively to provide bank stability. The Primary Sediment Pond is the collection point of sediment run-off. The pond is fed by Dairy Creek (back cover), which drains water from the Mortdale area. The creek bed is mostly exposed sandstone and varies in width from 3 to 5 m. There is a gross pollutant trap (Allison *et al.* 1997; Bennett 2002) along its 900 m length. Waterfall Creek drains into the transition zone between the Primary Sediment Pond and the Eastern Ridge Pond. Two small islands

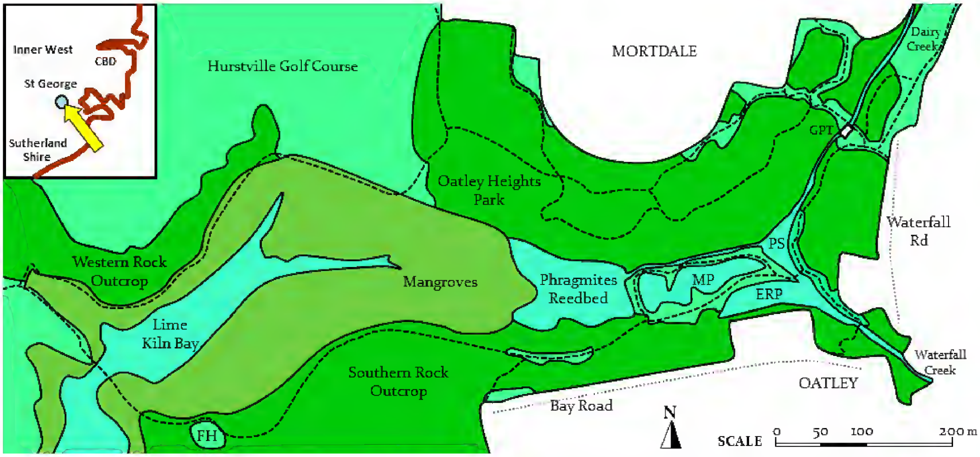

Fig. 1. Layout of the Lime Kiln Bay Wetland. Access tracks are marked in broken lines. Abbreviated names: FH=Frog's Hollow, MP=Macrophyte Pond, ERP=Eastern Ridge Pond, PS=Primary Sediment Pond, GPT=Gross Pollutant Trap. Inset map shows the location of the study area within the Sydney Metropolitan Area.

have been established in each pond as wildlife refuges. The purpose of the Eastern Ridge Pond is to disperse excess water away from the Macrophyte Pond (Fig. 2), reducing flooding pressures. The edges of the ponds are dominated by Common Reed *Phragmites australis*, Cumbungi *Typha domingensis* and Tall Sedge *Carex appressa*.

The Phragmites Reedbed is the last body of fresh water, separating the ponds from the tidal mangroves. The expanse of Common Reed covers approximately 1.2 ha. The upper reaches of Lime Kiln Bay support River Mangrove *Aegiceras corniculatum* and Grey Mangrove *Avicennia marina*. Three main areas of rocky outcrop form the ridges of the floodplain: Oatley Heights Park (Fig. 3) and the Western and Southern Rock Outcrops. The woodland is dominated by Sydney Red Gum *Angophora costata*, Red Bloodwood *Corymbia gummifera* and Sydney Peppermint *Eucalyptus piperita* (Mo 2014). The Lime Kiln Bay Wetland adjoins Oatley Park and Hurstville Golf Course in the south-west and north-west respectively.

Previous state and construction of the Lime Kiln Bay Wetland

The wetland differs markedly from its pre-restoration state (Fig. 4), which has been described as 'a weed-infested place, essentially a forest of privet and willow' (J Cockayne pers. comm). More specifically, the understorey was dominated by Broad Leaf Privet *Ligustrum lucidum*, Narrow Leaf Privet *L. sinense* and Pussy Willow *Salix cinerea*. The cover of these invasive weeds has been substantially reduced and they are subjected to frequent removal. Dense thickets of Giant Reed *Arundo donax*, a native species, occurred between Waterfall Creek and half of the area that is now the Primary Sediment Pond. Other prevalent weeds included Japanese Honeysuckle *Lonicera japonica*, Morning Glory *Ipomoea indica*, Madeira Vine *Anredera cordifolia*, Blackberry *Rubus fruticosus*, Cape Ivy *Delairea odorata*, Balloon Vine *Cardiospermum grandiflorum* and Tradescantia *Tradescantia fluminensis*. The native Common Reed always has been present and widespread, especially over the Eastern Ridge Water Course where it formed a continuous patch.

Construction of the Primary Sediment and Macrophyte Ponds occurred between 1999 and 2001 (Fig. 5). Hurstville City Council's volunteer bushcare program commenced in 1999, primarily carrying out bush regeneration along the boundaries during construction. Additional work to establish the current Eastern Ridge Pond from a shallow reedbed was undertaken between May and September 2005.

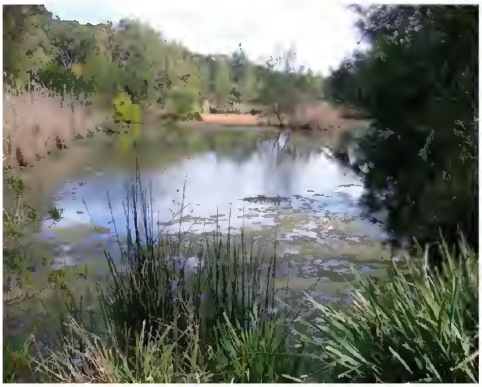

Fig. 2. Macrophyte Pond. Photo Oatley Flora and Fauna Conservation Society.

Fig. 3. Typical sandstone outcrop set in dry sclerophyll forest in Oatley Heights Park.

Fig. 4. A photograph of the wetland area in January 1999, which was taken in the same relative position as Fig. 2. A shallow reedbed covers the area that is now the Macrophyte Pond. Photo J Cockayne.

Species detection

The taxonomy in this paper follows Cogger (2014). Most data are derived from casual observations made by the author between 2006 and 2014 (one to seven visits per month). Observations of some species (mainly nocturnal, shade-loving or fossorial species) were aided by microhabitat disturbance from bush regeneration methods, e.g. clearing vegetation or moving rocks and fallen logs. Spotlighting was carried out on 20 nights between February and August 2010. Frogs were heard during the day and while spotlighting, and their calls were identified to species level by reference to Griffiths (2012). In addition, audio recordings were received from residents of adjoining properties. An effort was made to visit the study area after heavy rains to maximise the detection of frogs. Whenever possible, bushcare workers and park users on site were consulted for their personal fauna sightings. Additional records were obtained from the Atlas of Living Australia (ALA 2014) and Atlas of NSW Wildlife (Office of Environment and Heritage (OEH) 2014). Trapping methods were not used due to frequent visitation to the study area, which was a major limitation on species detection. Inaccessible parts of the study area (e.g. the Phragmites Reedbed and mangroves) were not studied.

Species assemblages for two other bushland remnants in the St George area were drawn on to place the results of this study into a regional context. Data for the Wolli Creek Valley (Manidis Roberts Consultants 1996; White and Burgin 2004; Department of Environment and Climate Change (DECC) 2007; Little *et al.*

Fig. 5. The western end of the Macrophyte Pond being dug with heavy machinery during the restoration project. Photo J Cockayne.

2010) and Rockdale Wetland Corridor (White and Burgin 2004; White 1999, 2002, 2010b) were based on secondary sources and the author's personal observations.

Results

A total of 23 species was detected over the study period (Table 1). Taking this as the complete inventory, it is notable that it passed the 50% mark in the first year of study (2006) and the 95% mark in the sixth year (2011) (Fig. 6). The three species detected in the last five years of the study were observed only once over the entire study period; these were the Eastern Brown Snake *Pseudonaja textilis* (2010), Smooth Toadlet *Uperoleia laevigata* (2011) and Copper-tailed Skink *Ctenotus taeniolatus* (2013).

The ALA (2014) and OEH (2014) databases yielded nine records of six species (Table 2), two of which were not detected in the present study: Black-bellied Swamp Snake *Hemiaspis signata*, one specimen collected in 1996; and Blackish Blind Snake *Ramphotyphlops nigrescens*, one specimen collected in 1997. As noted by Shea (2010), the former record is the last for the species in the St George area. The latter is a fossorial species (Webb and Shine 1992), which may explain the rarity of its detection.

Table 3 contextualises the results of this study with the herpetofauna assemblages of the Wolli Creek Valley (Manidis Roberts Consultants 1996; White and Burgin 2004; DECC 2007; Little *et al.* 2010) and Rockdale Wetland Corridor (White and Burgin 2004; White 1999, 2002, 2010b).

Frogs

Six species of frog were identified by call in this study; four of them also by sightings (Table 2). All were recorded only in the warmer months, except for the Striped Marsh Frog *Limnodynastes peronii*. It was heard during the day and night in thick vegetation (>50 cm tall) in water year round, and was observed only by spotlighting. It was most common in Waterfall Creek, Dairy Creek at the gross pollutant trap and temporary pools below the Southern Rock Outcrop. An adult was seen falling prey to a Red-bellied Black Snake *Pseudechis porphyriacus* (M Barbic pers. comm). The frog was concealed in leaf litter at the top of Waterfall Creek and was not seen until it was seized by the snake.

Leaf Green Tree Frog *Litoria phyllochroa* adults were seen by day huddled on the leaves of Elephant Ear *Colocasia esculenta* in Waterfall Creek. They were also seen by day when displaced from refuges in Tradescentia by bush regeneration operations along the narrow canal between the Macrophyte Pond and Oatley Heights Park and were also found here and in Dairy Creek during spotlighting. At night, individuals were sighted on rocks, soil banks and the fronds of low tree ferns (*Cyathea* sp.). The distribution of sightings reflects this species' preference for flowing water (Gillespie and Hines 1999; Hazell *et al.* 2004).

The Eastern Dwarf Tree Frog *L. fallax* was also observed during the day when disturbed by clearing of Tradescentia. It was more often

Table 1. Species inventory of herpetofauna in the Lime Kiln Bay Wetland. Detection methods: 0=opportunistic observation, BR=observation aided by bush regeneration work, S=spotlighting, CR=call recognition.

		O	BR	S	CR
Hylidae	Eastern Dwarf Tree Frog *Litoria fallax*		▪	▪	▪
	Peron's Tree Frog *Litoria peronii*			▪	▪
	Leaf Green Tree Frog *Litoria phyllochroa*	▪	▪	▪	▪
Limnodynastidae	Striped Marsh Frog *Limnodynastes peronii*			▪	▪
Myobatrachidae	Common Eastern Froglet *Crinia signifera*				▪
	Smooth Toadlet *Uperoleia laevigata*				▪
Cheluidae	Eastern Snake-necked Turtle *Chelodina longicollis*	▪		▪	
Agamidae	Eastern Water Dragon *Intellagama lesueurii lesueurii*	▪		▪	
Carphodactylidae	Broad-tailed Gecko *Phyllurus platurus*	▪		▪	
Scincidae	Eastern Water Skink *Eulamprus quoyii*	▪		▪	
	Greater Bar-sided Skink *Eulamprus tenuis*	▪			
	Copper-tailed Skink *Ctenotus taeniolatus*	▪			
	Weasel Skink *Saproscincus mustelina*		▪		
	Elegant Snake-eyed Skink *Cryptoblepharus pulcher pulcher*	▪			
	Pale-flecked Sunskink *Lampropholis guichenoti*	▪			
	Dark-flecked Sunskink *Lampropholis delicata*	▪			
	Three-toed Skink *Saiphos equalis*		▪		
	Eastern Blue-tongued Skink *Tiliqua scincoides*	▪			
Varanidae	Lace Monitor *Varanus varius*	▪			
Colubridae	Green Tree Snake *Dendrelaphis punctulata*	▪			
Elapidae	Red-bellied Black Snake *Pseudechis porphyriacus*	▪			
	Eastern Brown Snake *Pseudonaja textilis*	▪			
Pythonidae	Diamond Python *Morelia spilota spilota*	▪			

located by spotlighting perched on the blades of Spiny-headed Matrush. This species was apparently restricted to the Macrophyte Pond and nearby canal. Its call was heard by day and night, particularly after rainfall.

The Peron's Tree Frog *L. peronii* was sighted only once, clinging to the wall of a building near Waterfall Creek. On some nights, its calls were heard from around an artificial pond on an adjoining property and the Macrophyte Pond. Although calling frogs could not be seen, it was clear that they were located in elevated positions in Narrow-leaved Paperbarks.

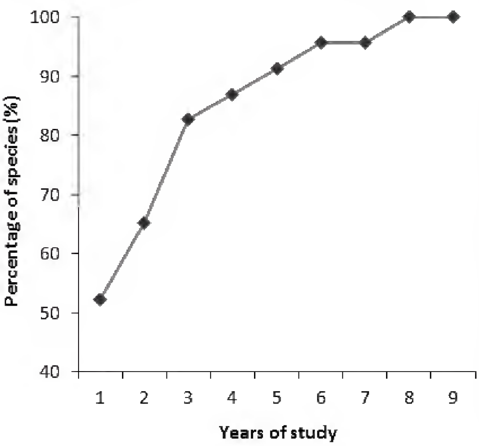

Fig. 6. Species accumulation curve.

The two smallest frog species, the Common Eastern Froglet and Smooth Toadlet, were heard but not sighted. The latter was restricted to a section of temporary pools below the Southern Rock Outcrop. The loud call of the Common Eastern Froglet was difficult to locate, but this species seemed to be widespread.

Turtles

The Eastern Snake-necked Turtle *Chelodina longicollis* is the only turtle known to occur in the study area (Table 1). It was shy and difficult to observe, mostly seen in spring and early summer when basking on the islands. In 2012 and 2013, turtles were seen basking on floating booms set up to catch suspended rubbish. They were also intermittently recorded asleep in Dairy Creek during spotlighting in March 2010. Except for one turtle travelling to the Macrophyte Pond from the nearby canal, no overland movements were recorded (Roe and Georges 2008). Carapace lengths of individuals observed were at least 15 cm, which may indicate low breeding

Table 2. Post-1980 records of frogs and reptiles in the Lime Kiln Bay Wetland from the ALA (2014) and OEH (2014) databases. *indicates species not detected in the present study.

		Year of records
Common Eastern Froglet	*Crinia signifera*	2011
Peron's Tree Frog	*Litoria peronii*	1998, 2010, 2011
Eastern Dwarf Tree Frog	*Litoria fallax*	2010
Three-toed Skink	*Saiphos equalis*	1981, 1999
Black-bellied Swamp Snake	*Hemiaspis signata**	1996
Blackish Blind Snake	*Ramphotyphlops nigrescens**	1997

Table 3. The herpetofauna assemblages of the Lime Kiln Bay Wetland in context with that of two other sites in the St George area. Data for the Wolli Creek Valley was adapted from Little *et al.* (2010), DECC (2007), White and Burgin (2004) and Manidis Roberts Consultants (1996). Data for the Rockdale Wetland Corridor was adapted from White and Burgin (2004) and White (1999, 2002, 2010b).

		Lime Kiln Bay Wetland	Wolli Creek Valley Corridor	Rockdale Wetland
Green and Golden Bell Frog	*Litoria aurea*			Y
Green Tree Frog	*Litoria caerulea*		Y	Y
Eastern Dwarf Tree Frog	*Litoria fallax*	Y	Y	
Bleating Tree Frog	*Litoria dentata*			Y
Peron's Tree Frog	*Litoria peronii*	Y	Y	Y
Leaf Green Tree Frog	*Litoria phyllochroa*	Y		
Striped Marsh Frog	*Limnodynastes peronii*	Y	Y	Y
Common Eastern Froglet	*Crinia signifera*	Y	Y	Y
Smooth Toadlet	*Uperoleia laevigata*	Y		
Eastern Snake-necked Turtle	*Chelodina longicollis*	Y	Y	Y
Jacky Lizard	*Amphibolurus muricatus*		Y	
Eastern Water Dragon	*Intellagama lesueurii lesueurii*	Y	Y	
Broad-tailed Gecko	*P hyllurus platurus*	Y	Y	
Eastern Water Skink	*Eulamprus quoyii*	Y	Y	Y
Greater Bar-sided Skink	*Eulamprus tenuis*	Y	Y	
Copper-tailed Skink	*Ctenotus taeniolatus*	Y	Y	
Weasel Skink	*Saproscincus mustelina*	Y	Y	Y
Elegant Snake-eyed Skink	*Cryptoblepharus pulcher pulcher*	Y	Y	Y
Pale-fleckered Sunskink	*Lampropholis guichenoti*	Y	Y	Y
Dark-fleckered Sunskink	*Lampropholis delicata*	Y	Y	Y
Three-toed Skink	*Saiphos equalis*	Y	Y	Y
Eastern Blue-tongued Skink	*Tiliqua scincoides*	Y	Y	Y
Lace Monitor	*Varanus varius*	Y		
Green Tree Snake	*Dendrelaphis punctulata*	Y		
Yellow-faced Whip Snake	*Demansia psammophis*			Y
Red-bellied Black Snake	*Pseudechis porphyriacus*	Y	Y	Y
Eastern Brown Snake	*Pseudonaja textilis*	Y		
Diamond Python	*Morelia spilota spilota*	Y		
Total		**23**	**19**	**15**

success in the St George area (Little *et al.* 2010), but is more probably due to the greater likelihood of sighting larger animals.

Bushcare workers and park users mentioned they had seen people release turtles into the wetland, presumably pets or rescued animals from suburbia (J Cockayne, B Groves and R Staples pers. comm). It is not known whether these releases were of other species of turtle.

Skinks

Seven of the nine skink species were readily observed by day. The remaining two species, the saxicolous Three-toed Skink *Saiphos equalis* and shade-loving Weasel Skink *Saproscincus mustelina* were recorded by microhabitat disturbance by bush regeneration operations. The former were particularly numerous under logs at the Frog's Hollow clearing (Fig. 1).

All but three skink species were found in the wetland area. The Elegant Snake-eyed Skink *Cryptoblepharus pulcher pulcher* was restricted to the built environs along the boundary of the study area, and the Greater Bar-sided Skink *Eulamprus tenuis* and Copper-tailed Skink were restricted to the Southern Rock Outcrop. Five species (Eastern Water Skink *E. quoyii*, Pale-flecked Sunskink *Lampropholis guichenoti*, Dark-flecked Sunskink *L. delicata*, Three-toed Skink and Eastern Blue-tongued Skink *Tiliqua scincoides scincoides*) were widespread in the valley and on the sandstone slopes. The Eastern Water Skink was conspicuous during the day, and was also found in sandstone crevice retreats in Oatley Heights Park at night. The two sunskinks and the Elegant Snake-eyed Skink were the only species commonly observed over the cooler months.

Agamids

The only agamid species was the Eastern Water Dragon *Intellagama lesueurii lesueurii*, found in all waterside areas. Its population appears to have increased in density since wetland construction (R Casey pers. comm). The rocky embankments of Dairy Creek were a focal area of its distribution, particularly around the gross pollutant trap. It also occurred in adjoining backyards, and some mature males may have established territories (Thompson 1993) there. Faithfulness to home sites was evident in some animals with distinctive markings. For at least four years one individual with a broken tail was seen frequently in the warmer months on a property off Bay Road (B Groves pers. comm). Rock crevices were the main retreat sites, although individuals were also found sleeping overnight on tree trunks and underwater. Some poaching of this species has been reported (J Cockayne pers. comm), but it was still numerous.

A second agamid species, the Eastern Bearded Dragon *Pogona barbata* disappeared from the St George area in the early 1990s. It was formerly common in the Southern Rock Outcrop, and individuals often basked on Bay Road, where many were run over (R Staples pers. comm). The closest known population is now located in Georges River National Park (NPWS 1994).

Other lizards

One species of gecko, the Broad-tailed Gecko *Phyllurus platurus* occurred in the study area. It was found in all rock outcrops and was particularly abundant in Oatley Heights Park, where a population study detected densities of up to three animals per 100 m^2 of rock wall surface (Mo 2014). On five occasions, geckoes were found co-habiting in crevices with Eastern Water Skinks. In one large sandstone crevice, up to 12 geckoes could be seen during the day at any time of year. This species also occurred on brick walls of some adjoining properties (B Groves pers. comm), and has been noted in other locations (Green 1973; White and Burgin 2004).

A single Lace Monitor *Varanus varius* was sighted in December 2005 between the Macrophyte Pond and Bay Road (J Cockayne pers. comm). In the early 2000s, this species was seen intermittently in Oatley Park, adjoining the study area (R Staples pers. comm). More recently, it has been observed in other bushland remnants along the Georges River in the Hurstville area (V Willes pers. comm; pers. obs). Monitors possibly access the habitat remnants from larger tracts of bushland, e.g. Georges River National Park (NPWS 1994) and the Menai district (L Hedges and A Turnbull pers. comm).

Snakes

Four species of snake have been recorded (Table 2); however, only the Red-bellied Black Snake was commonly seen. Between 1999 and 2003, it was encountered by bushcare workers on most days in the warmer months, particularly during wetland construction when the Eastern Ridge Pond was being converted from a reedbed. Numbers appear to have declined from 2004 onwards. Prior to this study, it could be found in locations as elevated as Oatley Heights Park (J Cockayne pers. comm), which is up to 8 m higher than the wetland. However, during this study, it was confined to the immediate wetland area and Dairy and Waterfall Creeks, with one isolated observation in Hurstville Golf Course (Fig. 1) in December 2008—this snake retreated to the mangroves. This species may also have been present in the Phragmites Reedbed, which was not accessible to this study.

A large Red-bellied Black Snake (>2 m in length; ~10 cm in girth) was seen by various people at least 15 times between 2002 and 2012, including three times on an adjoining property on Bay Road, where it was observed at close range (B Groves pers. comm). In 2003, between clumps of Spiny-headed Matrush on the banks of the Macrophyte Pond, male combat was witnessed, in which several smaller snakes were coiled around the large individual (J Cockayne pers. comm).

An adult Eastern Brown Snake was observed in November 2010 in the western portion of Oatley Heights Park. There were three sightings of the Diamond Python *Morelia spilota spilota*, all adults; two in trees on the edge of the mangroves, and one active on the ground (P Hayler pers. comm). The Green Tree Snake *Dendrelaphis punctulata* was recorded twice: once on the walking track in the Western Rock Outcrop in December 2009 and on a tree near Frog's Hollow in February 2012.

Discussion

The status of herpetofauna in urban landscapes has received increasing attention in recent times (Anderson and Burgin 2002; Koenig *et al.* 2002; Jellinek *et al.* 2004; Butler *et al.* 2005a, b; Cogger 2010; Hamer and McDonnell 2010; Wotherspoon and Burgin 2011; Mo 2014). Considerable interest has focused on Sydney (e.g. Murphy 1996; Murphy 2010; Shea 2010) as the largest and oldest city in Australia. Although this study focused on an area smaller than both the Wolli Creek Valley and Rockdale Wetland Corridor, more species were recorded for the Lime Kiln Bay Wetland than at these sites. The species assemblage of the Lime Kiln Bay Wetland probably provides a fair representation of the herpetofaunal diversity of the wider St George area.

Biodiversity in remnant bushland is clearly related to habitat complexity (Wilks 2010). For example, the presence of flowing water is important for the persistence of the Leaf Green Tree Frog (Gillespie and Hines 1999), an amphibian species that was not detected in the other sites. The Broad-tailed Gecko and Greater Bar-sided Skink were associated with remnant sandstone formations, a habitat that is lacking in the Rockdale Wetland Corridor. The Oatley bushland corridor is considered a significant area for the Greater Bar-sided Skink in the Sydney region (Griffiths 2012).

This study adds significantly to the sparse records in atlas databases (ALA 2014; OEH 2014), which appear to be limited to unusual findings, with more common species apparently overlooked. A comprehensive fauna inventory is generally achieved only when the data have been collected over a substantial period and by multiple surveying techniques (Murphy and Murphy 2011). This allows for variation in seasonal conditions (Sass *et al.* 2011) and increases the likelihood of cryptic and rare species being detected. From a management perspective, records of declining species are perhaps the most valuable information provided by a site inventory. The prime example in this study is the Copper-tailed Skink, a declining species in the Sydney Metropolitan Area (Murphy 2010; Shea 2010), which was detected only towards the conclusion of the study.

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A survey of the marine bivalves and gastropods of Shelly Beach, Port Macquarie, on the north coast of New South Wales, Australia

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Abstract

The New South Wales (NSW) north coast has a diverse marine bivalve and gastropod fauna of biogeographical interest. A field survey at Shelly Beach, on the NSW lower north coast over the period 2009-2015, complemented by a review of data from secondary sources, identified 142 species comprising 34 bivalves (24 families) and 108 gastropods (51 families). It is likely that further survey effort, particularly targeting micro-molluscs less than 5 mm in size, would identify additional species. The molluscan fauna of Shelly Beach reflects the location of the NSW north coast in an overlap zone between the tropical Indo-West Pacific region to the north and the temperate southern Australian region to the south. Temperate zone species comprised about 63% of the identified species diversity, sub-tropical species about 20%, overlap zone endemics about 12% and widespread species about 5%. (*The Victorian Naturalist* **132** (3) 2015, 73–85)

Keywords: marine molluscs, Indo-West Pacific fauna, Palaeo-Austral fauna, eastern overlap zone, Manning Shelf bioregion

Introduction

Australia has a rich marine mollusc fauna of global significance (Ponder *et al.* 2002). The tropical and sub-tropical coastal waters of northern Australia have high species diversity and form part of the extensive Indo-West Pacific bioregion, stretching from the east coast of Africa to Hawaii, while the temperate coastal waters of southern Australia support an ancient Palaeo-Austral fauna with fewer species but high levels of endemism (Ponder and Wells 1998; Ponder *et al.* 2002; Wilson 2010). Transitional or overlap zones of warm temperate waters along the east and west coasts of Australia contain a mix of southern and northern elements as well as some local endemics (Ponder and Wells 1998; Ponder *et al.* 2002; Reid and Williams 2004; Beechey 2012). The New South Wales (NSW) north coast lies in the heart of the eastern overlap zone (Ponder *et al.* 2002; Wilson 2010; Beechey 2012) and is an interesting area for the study of marine molluscs. The results of a field study of the marine bivalves and gastropods of a single site on the NSW north coast is presented here as an example of the region's marine mollusc fauna and to help promote a wider appreciation of this fauna's diversity and significance.

Study Area and Methods

Shelly Beach (31°27'S, 152°56'E) (Fig. 1) is located at Port Macquarie in Biripi Aboriginal Country, 310 km north-east of Sydney on the lower north coast of NSW, Australia. It is situated in the northern part of the Manning Shelf marine and coastal bioregion, which extends from Stockton (north of the Hunter River) to north of Nambucca Heads, and the northern part of the Central Eastern marine and coastal province, which extends from Lake Illawarra near Wollongong to Coffs Harbour (Commonwealth of Australia 2006). The beach is about 1200 m long and includes areas of sandy beach, cobble/boulder beach and intertidal rock platform with an underlying geology of serpentinite, basalt and dolerite (Och *et al.* 2007). A near-shore rocky reef is located towards the southern end of the beach. Shelly Beach is within the Port Macquarie urban area but the land immediately adjacent to the beach supports littoral rainforest, part of which is protected within Sea Acres Nature Reserve.

Observations on the marine bivalves and gastropods at Shelly Beach were made during diurnal site visits on 10 occasions between December 2009 and February 2015, predominantly during the austral summer months but also including visits in autumn, winter and spring (Appendix 1). Field survey methods comprised visual examination of accumulated deposits of shell material (molluscan death assemblages) (Fig. 2), beachcombing for fresh shells along

Fig. 1. View of Shelly Beach, Port Macquarie, NSW.

Fig. 2. Close-up view of a mollusc death assemblage (shell deposit) at Shelly Beach. At least 10 mollusc species can be seen in this photograph.

the strandline, searches of intertidal habitats for live animals during low tide and investigation of shallow sub-tidal areas by snorkelling. No sorting of shell grit under magnification was done to identify micro-molluscs, so that the field survey covered only species of about 5 mm or larger. Shelled species were identified by reference to Dakin and Bennett (1987), Wilson (1993), Wilson (1994), Jansen (2000), Grove (2011), Beechey (2012), Beechey (Australian Museum, Sydney) (pers. comm.) and communication with other experts (see acknowledgements). Sea slug specimens were photographed *in situ* and were identified by Rudman (Australian Museum) (pers. comm.). Reference was also made to the Australian Museum collection database (data supply April 2014) and to data from a 2008 survey by Smith (2009) for records of additional species from the Shelly Beach study area.

The broad habitat preference and distribution in Australia of each species were determined by reference to Lamprell and Whitehead (1992), Wilson (1993), Wilson (1994), Brodie *et al.* (1997), Lamprell and Healey (1998), Malaquias and Reid (2008), Grove (2011), Beechey (2012) and the Atlas of Living Australia (2014). Four habitat categories were used: soft substrates (sand or mud), rocky substrates, pelagic, and other (e.g. attached to other fauna). Categories used for distribution in Australia were northern (tropical/subtropical), southern (temperate), eastern overlap zone or cosmopolitan. The relative abundance of species detected during the field survey was also recorded. Categories used were abundant (recorded in large numbers on most visits), common (regularly recorded in small to moderate numbers), uncommon (irregularly recorded in small numbers) or rare (three or fewer specimens recorded over duration of survey).

Results and Discussion

A total of 101 species (21 bivalves and 80 gastropods) was recorded over the duration of the field study (Table 1). Nine species were recorded as abundant, 28 as common, 31 as uncommon and 33 as rare. Abundant species included *Donax deltoides*, *Cellana tramoserica*, *Turbo undulatus*, *Austrocochlea porcata*, *Bankivia fasciata* and *Nerita atrementosa*. An additional 41 species from Shelly Beach were identified from secondary sources. The final total of 142 species (Table 1) comprised 34 bivalves (24 families) and 108 gastropods (51 families). The most speciose families were the Cypraeidae (seven species), Ranellidae (seven), Muricidae (seven) and Trochidae (six). Thirty-four species from the present field survey (seven bivalves and 27 gastropods) were additional to the list of species previously known from Shelly Beach (Smith 2009; Australian Museum data).

The present field study did not include micro-molluscs, with the smallest shells identified being *Cantharidella picturata* (5–7 mm), *Nodilittorina unifasciata* (6 mm) and *Bullina lineata* (7.5 mm). The survey by Smith (2009) also documented only species 5 mm or greater in size. Sampling and sorting of shell grit under magnification would be expected to identify a range of micro-mollusc species of less than 5 mm size at Shelly Beach. Marine micro-mollus-

Table 1. Marine bivalve and gastropod species recorded at Shelly Beach, Port Macquarie. Taxonomy follows Lamprell and Whitehead (1992) and Lamprell and Healey (1998) for bivalves and Beechey (2012) for gastropods, with reference to Brodie *et al.* (1997), Jansen (2000), Malaquias and Reid (2008), Wilson (1993), Wilson (1994) and Atlas of Living Australia (2014) for taxa not covered by Beechey. * = record from Australian Museum Malacology collection database. # = 2008 record from Smith (2009) survey provided by Smith (pers. comm.). **Habitat (Hab):** R = rocky, S = soft sediment (sand or mud), P = pelagic, O = other. **Distribution (Dist):** S = southern, N = northern, E = eastern overlap, C = cosmopolitan. **Local status (Loc stat):** A = abundant, C = common, U = uncommon, R = rare.

Family	Scientific name	Common name	Hab	Dist	Loc stat
Bivalvia					
Arcidae	*Anadara trapezia* (Deshayes, 1840)	Sydney Cockle	S	S	C
	Barbatia pistachia (Lamarck, 1819)	Hairy Ark-shell	R	S	C
Glycymeridae	*Glycymeris grayana* (Dunker, 1857)	Gray's Dog-cockle	S	S	U
Mytilidae	*Gregariella splendida* (Dunker, 1857) #		R	E	-
	Trichomya hirsutus (Lamarck, 1819)	Hairy Mussel	R	S	C
	Xenostrobus securis (Lamarck, 1819) *	Little Brown Mussel	S	S	-
Pteriidae	*Pinctada fucata* (Gould, 1850)	Akoya Pearl Oyster	S	N	C
Malleidae	*Vulsella vulsella* (Linnaeus, 1758) #	Sponge Finger Oyster	O	C	-
Pectinidae	*Pecten fumatus* Reeve, 1852	Southern Scallop	S	S	R
	Scaeochlamys livida (Lamarck, 1819)	Scaly Scallop	R	N	C
Spondylidae	*Spondylus tenellus* Reeve, 1856 #	Slender Thorny-Oyster	O	S	-
Anomiidae	*Anomia trigonopsis* Hutton, 1877 #	Jingle Shell	R	S	-
	Monia deliciosa Iredale, 1936 #		S	S	-
Limidae	*Lima nimbifer* Iredale, 1924	Cloud File-shell	R	S	R
Ostreidae	*Saccostrea glomerata* (Gould, 1850)	Sydney Rock Oyster	R	E	U
Chamidae	*Chama fibula* Reeve, 1846	Brooch Jewel-box	R	N	C
Galeommatidae	Galeommatidae species 1 #		-	-	-
Carditidae	*Cardita excavata* Deshayes, 1854	Excavated False-cockle	S	S	C
Cardiidae	*Acrosterigma kerslakae* Healy & Lamprell 1992 #		S	E	-
	Acrosterigma species 2	Cockle species	S	-	R
	Vepricardium multispinosum (Sowerby, 1838)	Many-spined Heart Cockle	S	N	R
Hemidonacidae	*Hemidonax dactylus* Hedley, 1923 #		S	N	-
Mactridae	*Mactra contraria* Reeve, 1854	Moon Pipi	S	S	C
Tellinidae	*Tellina botanica* (Hedley, 1918)	Tellen species	S	S	U
Donacidae	*Donax brazieri* Smith, 1892	Brazier's Wedge Shell	S	S	C
	Donax deltoides Lamarck, 1818	Common Pipi	S	S	A
Veneridae	*Bassina pachyphylla* (Jonas, 1839)	Faintly-frilled Venus	S	S	U
	Irus crenatus (Lamarck, 1818) #	Boring Venus Shell	R	S	-
	Irus cumingii (Deshayes, 1854)	Cuming's Boring-venus	R	S	C
Corbulidae	*Corbula coxi* Pilsbry, 1897 #	Basket-shell	S	C	-
Hiatellidae	*Hiatella australis* Lamarck, 1818 #	Australian Rock-borer	R	C	-
Pholadidae	*Pholas australasiae* Sowerby, 1849	Australian Angel-wing	R	S	R
Cleidothaeridae	*Cleidothaerus albidus* (Lamarck, 1819) #	White Rock-clam	R	S	-
Lucinidae	*Codakia rugifera* (Reeve, 1835)	Ridged Lucine	S	S	U
Gastropoda					
Nacellidae	*Cellana tramoserica* (Holten, 1802)	Variegated Limpet	R	S	A
Patellidae	*Scutellastra chapmani* (Tenison Woods, 1876)	Star Limpet	R	S	C
	Scutellastra peronii (Blainville, 1825)	Scaly Limpet	R	S	C
Lottiidae	*Notoacmea petterdi* (Tenison Woods, 1876) #	Petterd's Limpet	R	S	-
	Patelloida latistrigata (Angas, 1865) #	Lateral-striped Limpet	R	S	-
	Patelloida mufria (Hedley, 1915) #		R	S	-
Haliotidae	*Haliotis coccoradiata* Reeve, 1846	Reddish-rayed Abalone	R	S	R
	Haliotis rubra Leach, 1814	Blacklip Abalone	R	S	U
Fisurellidae	*Amblychilepas nigrita* (Sowerby, 1834)	Keyhole Limpet	R	S	U
	Montfortula rugosa (Quoy & Gaimard, 1834)	Slit Limpet	R	S	C
	Diodora lineata (Sowerby, 1835)	Lined Keyhole Limpet	R	S	C
	Scutus antipodes Montfort, 1810	Black Elephant Snail	R	S	C
	Tugali parmophoidea (Quoy & Gaimard, 1834)	Parmophoid Notch-limpet	R	S	R

Table 1. cont'd

Family	Scientific name	Common name	Hab	Dist	Loc stat
Turbinidae	*Turbo torquatus* Gmelin, 1791	Sydney Turban Shell	R	S	U
	Turbo undulatus Solander, 1786	Green Turban Shell	R	S	A
	Turbo militaris Reeve, 1848	Military Turban Shell	R	E	R
	Astralium tentoriiformis (Jonas, 1845)	Tent shell	R	E	C
Trochidae	*Austrocochlea porcata* (Adams, 1851)	Zebra Periwinkle	R	S	A
	Austrocochlea concamerata (Wood, 1828)	Wavy Periwinkle	R	S	R
	Herpetopoma aspersa (Philippi, 1846)	Speckled Top-shell	R	S	C
	Cantharidella picturata (Adams & Angas, 1864)	Painted Kelp-shell	R	S	U
	Phasianotrochus eximius (Perry, 1811)	Kelp Shell	R	S	C
	Bankivia fasciata (Menke, 1830)	Banded Sand Shell	S	S	A
Neritidae	*Nerita atrementosa* Reeve, 1855	Black Periwinkle	R	S	A
Turritellidae	*Gazameda gunnii* (Reeve, 1849)	Gunn's Screw-shell	S	S	R
Batillariidae	*Pyrazus ebeninus* (Bruguiere, 1792)	Hercules Club Mud Whelk	S	N	U
	Batillaria australis (Quoy & Gaimard, 1834)	Australian Mud Whelk	S	S	R
Littorinidae	*Bembicium nanum* (Lamarck, 1822)	Striped-mouth Conniwink	R	S	A
	Austrolittorina unifasciata (Gray, 1826)	Blue Periwinkle	R	S	A
	Nodilittorina pyramidalis (Quoy & Gaimard, 1833)	Pyramid Periwinkle	R	E	A
Hydrobiidae	*Tatea huonensis* (Tenison Woods, 1876) *		S	S	-
Struthiolariidae	*Tylospira scutulata* (Gmelin, 1791)	Ostrich Foot Shell	S	E	U
Hipponicidae	*Antisabia aff. foliacea* (Quoy & Gaimard, 1835)	Horse Hoof Limpet	R	S	U
	Malluvium devotum (Hedley, 1904)	Devoted Bonnet-limpet	O	S	R
Calyptraeidae	*Sigapatella hedleyi* Smith, 1915	Hedley's Shelf-limpet	O	S	R
Cypraeidae	*Cypraea caputserpentis* Linnaeus, 1758	Serpent's-head Cowrie	R	N	U
	Cypraea erosa Linnaeus, 1758	Gnawed Cowrie	R	N	U
	Cypraea errones Linnaeus, 1758	Wandering Cowrie	R	N	U
	Cypraea felina Gmelin, 1791	Kitten Cowrie	R	N	U
	Cypraea flaveola Linnaeus, 1758	White-spotted Cowrie	R	N	R
	Cypraea subviridis Reeve, 1835 #	Greenish Cowry	R	N	-
	Cypraea teres Gmelin, 1791	Tapering Cowrie	R	N	R
Natacidae	*Conuber conicum* (Lamarck, 1822)	Conical Moon Snail	S	S	U
	Glossaulax didyma (Roding, 1798)	Bladder Moon Snail	S	N	C
	Natica gualtieriana Recluz, 1844	Gualtieri's Natica	S	N	U
	Neverita incei (Philippi, 1853)	Ince's Moon Snail	S	S	C
Tonnidae	*Tonna cerevisina* Hedley, 1919	Tun Shell	S	E	U
Cassidae	*Semicassis labiatum* (Perry, 1811) #	Helmet Shell	S	S	-
	Semicassis pyrum (Lamarck, 1822)	Pear Bonnet	S	S	R
Ranellidae	*Cabestana spengleri* (Perry, 1811)	Spengler's Rock-whelk	R	S	C
	Charonia lampas rubicunda (Perry, 1811) #	Knobbed Triton	R	S	-
	Cymatium labiosum (Wood, 1822) * #	Wide-lipped Triton	R	N	-
	Cymatium parthenopeum (von Salis, 1793)	Hairy Oyster Borer	R	S	R
	Cymatium exaratum (Reeve, 1844)	Shouldered Triton	R	S	R
	Ranella australasia (Perry, 1811)	Australasian Rock-whelk	R	S	C
	Sassia parkinsonia (Perry, 1811) #	Parkinson's Triton	R	S	-
Janthinidae	*Janthina janthina* (Linnaeus, 1758)	Common Violet Sea Snail	P	C	R
Epitoniidae	*Opalia australis* (Lamarck, 1822)	Austral Wentletrap	R	S	U
	Opalia ballinensis (Smith, 1891)	Ballina Wentletrap	R	E	R
Muricidae	*Agnewia tritoniformis* (Blainville, 1832)	Triton-like Rock-shell	R	S	U
	Chicoreus denudatus (Perry, 1811) #	Denuded Murex	R	S	-
	Coralliophila squamosissima (Smith, 1876) *		R	N	-
	Cronia aurantiaca (Hombron & Jaquinot, 1853)		R	N	U
	Dicathais orbita (Gmelin, 1791)	Common Cartrut-shell	R	S	C
	Lepsiella reticulata (Blainville, 1832) * #	Net Lepsiella	R	S	-
	Morula marginalba (Blainville, 1832)	Mulberry Shell	R	N	C
Buccinidae	*Cominella eburnea* (Reeve, 1846)	Ivory Whelk	S	S	C

Table 1. cont'd

Family	Scientific name	Common name	Hab	Dist	Loc stat
Columbellidae	*Mitrella tayloriana* (Reeve, 1859)	Taylor's Dove-shell	R	S	U
Nassariidae	*Nassarius gaudiosus* (Hinds, 1844)	Pointed Dog Whelk	S	N	R
	Nassarius jonasii (Dunker, 1846) #	Jonas' Dog Whelk	S	S	-
	Nassarius nigellus (Reeve, 1854) #	Tasmanian Dog Whelk	S	S	-
Volutidae	*Amoria undulata* (Lamarck, 1804)	Wavy Volute	S	S	R
	Amoria zebra (Leach, 1814)	Zebra Volute	S	E	C
	Cymbiola magnifica (Gebauer, 1802)	Magnificent Volute	S	E	R
Olividae	*Amalda marginata* (Lamarck, 1811)	Margined Olive	S	S	R
Pseudolividae	*Zemira australis* (Sowerby, 1833)	Southern False-olive	S	S	R
Marginellidae	*Austroginella muscaria* (Lamarck, 1822)	Fly-like Margin-shell	S	S	U
	Austroginella johnstoni (Petterd, 1884)	Johnston's Margin-shell	S	S	U
Mitridae	*Mitra cookii* Sowerby, 1874	Cook's Mitre	R	E	R
Cancellariidae	*Cancellaria undulata* Sowerby, 1849 #		S	S	-
Conidae	*Conus aplustre* Reeve, 1843	Back-end Cone	R	E	U
Turridae	*Epidirona hedleyi* Iredale, 1931 #	Striated Turrid	S	E	-
Terebridae	*Hastula brazieri* (Angas, 1871)	Brazier's Auger	S	S	R
Architectonicidae	*Adelphotectonica reevei* (Hanley, 1862)	Reeve's Sundial-shell	S	S	R
	Philippia lutea (Lamarck, 1822)	Yellow Sundial-shell	R	S	U
Bullidae	*Bulla quoyi* Gray, 1843 *		S	S	-
	Bulla vernicosa Gould, 1859		S	N	U
Hydatinidae	*Hydatina physis* (Linnaeus, 1758)	Paper Bubble	R	N	U
Bullinidae	*Bullina lineata* Gray, 1825	Lined Bubble-shell	R	N	R
Planaxidae	*Hinea brasiliana* (Lamarck, 1822)	Clusterwink	R	S	C
Trimusculidae	*Trimusculus conica* Angas, 1864 #	Conical Lung-limpet	R	S	-
Ellobiidae	*Ophicardelus quoyi* H. & A. Adams, 1855 *		S	S	-
	Ophicardelus sulcatus H. & A. Adams, 1855 *		S	S	-
Siphonariidae	*Siphonaria denticulata* Quoy & Gaimard, 1833	Denticulated Siphon Shell	R	S	C
	Siphonaria funiculata Reeve, 1856 #	Corded Siphon Shell	R	S	-
Umbraculidae	*Umbraculum umbraculum* (Lightfoot, 1786)	Umbrella-shell	R	N	U
Aplysiidae	*Aplysia dactylomela* Rang, 1828	Spotted Sea Hare	R	N	R
	Aplysia parvula Guilding in Morch, 1863 *	Dwarf Sea Hare	R	C	-
	Dolabrifera brazieri Sowerby, 1870	Sea Hare species	R	E	R
Dendrodorididae	*Dendrodoris fumata* (Ruppell & Leuckart, 1830) *	Sea-slug species	R	C	-
	Dendrodoris nigra (Stimpson, 1855)	Black Sea-slug	R	N	U
Dorididae	*Jorunna pantherina* (Angas, 1864)	Sea-slug species	R	N	R
	Rostanga arbutus (Angas, 1864)	Sea-slug species	R	E	R
Glaucidae	*Austraeolis ornata* (Angas, 1864) *	Sea-slug species	R	S	-
	Phyllodesmium serratum (Baba, 1949) *	Sea-slug species	R	C	-
Elysiidae	*Elysia maoria* Powell, 1937 *	Sea Slug species	R	E	-
Limapontiidae	*Placida dendritica* (Alder & Hancock, 1843) *	Sea Slug species	R	S	-
Pleurobranchidae	*Pleurobranchus peroni* Cuvier, 1804 *	Peron's Side-gill Slug	R	N	-

can fauna known from within 20 km of Shelly Beach include members of the Anabathridae, Anatomidae, Pyramidellidae, Rissoidae and Skeneidae (Australian Museum data).

Information on broad distribution and habitats of the Shelly Beach fauna identified in this study is included in Table 1 and summarised in Fig. 3. Southern (temperate) species dominated the bivalve species diversity, with a mix of sandy and rocky habitat species including *Anadara trapezia*, *Donax deltoides* and *Bassinia pachyphylla* (sandy) and *Barbatia pistachia*, *Trichomya hirsutus* and *Anomia trigonopsis* (rocky). The gastropod species diversity was also dominated by southern species, of which most were rocky shore species including *Cellana tramoserica*, *Turbo undulatus*, *Austrocochlea porcata* and *Bembicium nanum*. Northern (sub-tropical) fauna comprised about 20% of total recorded species diversity at Shelly Beach and included

Scaeochlamys livida, Vepricardium multispinosum, the seven cowries, *Natica gualtieriana, Cronia aurantiaca* and *Hydatina physis.*

Over half (57%) of the species recorded at Shelly Beach are Australian endemics. Most of these are temperate species from southern Australia and include *Trichomya hirsutus, Glycymeris grayana, Codakia rugifera, Haliotis rubra, Turbo torquatus, Austrolittorina unifasciata* and *Chicoreus denudatus.* Some of these temperate endemic species form part of the ancient Palaeo-Austral fauna. Williams *et al.* (2003), for example, suggested that *Austrolittorina* species may have been present on the shores of Gondwana since the Cretaceous. Another suite of species is endemic or largely restricted to the eastern Australian overlap zone. This group makes up about 12% of the recorded Shelly Beach fauna and includes *Turbo militaris, Nodilittorina pyramidalis, Tylospira scutulata, Opalia ballinensis, Mitra cookii* and *Rostanga arbutus.*

Several species recorded in this study represent extensions of known range. The record of *Austrocochlea concamerata* (Fig. 4) is a 150 km northerly extension from the previous limit at Port Stephens (Beechey 2012) and the record of *Nassarius gaudiosus* (Fig. 4) is a 150 km southerly range extension from the previous limit at Woolgoolga north of Coffs Harbour (Beechey 2012). Both species were rarely recorded at Shelly Beach, with only two *A. concamerata* and one *N. gaudiosus* shells found over the duration of the study.

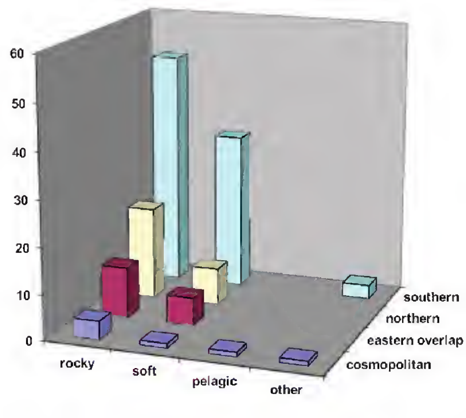

Fig. 3. Number of species in identified Shelly Beach fauna broken down by broad habitat and distribution categories.

Many of the species found at Shelly Beach were recorded only as dead shells, either as part of death assemblages or as fresh shells on the strandline. Examples include *Bassina pachyphylla, Pyrazus ebineus, Tonna cerevisina, Janthina janthina, Opalia australis* and *Cymbiola magnifica.* Molluscan death assemblages typically contain notably higher species richness than the local live community at a site, due to time-averaging of species richness (i.e. live species appearing and disappearing from the local community as environmental conditions vary over time but all persisting in the death assemblage) as well as post-mortem transport of shells from nearby different habitats by waves and currents (Kidwell 2002; Warwick and Light 2002; Smith 2008). Sampling of death assemblages can therefore provide a more complete species inventory than one-off live-sampling and can be an efficient tool for assessing regional species diversity for near-shore habitats (Warwick and Light 2002; Smith 2008). Conversely, identification of non-shelled molluscs such as nudibranchs necessarily relies on live survey.

A statewide assessment of marine intertidal molluscan death assemblages by Smith (2009) found the Port Macquarie area to have a relatively low species diversity of near-coastal marine molluscs compared to neighboring areas to both the north and south, and he conjectured that this might be related to a low amount of near-shore reef habitat resulting in absence or scarcity of some rocky habitat species in local death assemblages. Observations at Shelly Beach over an extended period and including live surveys added substantially to the list of 88 species compiled by Smith (2009) in a single two hour search, with many of these being rocky habitat species. Nevertheless, Smith's (2009) assessment of Shelly Beach as relatively depauperate remains broadly valid. The 142 species for Shelly Beach documented in this study can be compared, for example, to over 330 species at Mulloway Headland near Coffs Harbour (based on 40 surveys over a six year period) (Smith 2009).

Species were added over the duration of the present field survey, including two species found only in February 2015, and it is likely that further survey effort at Shelly Beach would identify additional species. The Austral-

Fig. 4. *Austrocochlea concamerata* (left) and *Nassarius gaudiosus* (right).

ian Museum has records of approximately 290 marine bivalve and gastropod species found within 20 km of Shelly Beach (between about Point Plomer to the north and Laurieton to the south) (Australian Museum data), of which 215 are additional to the present study. Some of these are micro-molluscs not covered in the present study while others are pelagic, deep-sea or estuarine species not likely to be often found at Shelly Beach. It is also noteworthy that 51 species (14 bivalves and 37 gastropods) recorded in the field survey component of the present study were not known from Australian Museum records to occur within 20 km of Shelly Beach, including several large and relatively common species such as *Mactra contraria*, *Donax deltoides*, *Scutus antipodes*, *Turbo torquatus* and *Astralium tentoriiformis*. These two points demonstrate the significant reference value of public museum collections, amassed over a period of greater than a century, and the need for ongoing work to maintain and continue building these collections.

Some of the interesting marine molluscs found at Shelly Beach are illustrated. Information on general biology is from Lamprell and Whitehead (1992), Wilson (1993), Wilson (1994), Brodie *et al.* (1997), Lamprell and Healey (1998), Rudman (1999), Rudman (2002), Rudman (2003), Grove (2011) and Beechey (2012). *Bassina pachyphylla* and *Glycymeris grayana* (Fig. 5) are both endemic, living in littoral sands in south-eastern Australia. They each have distinctively patterned shells, the former rusty-brown in colour with paler radiating bands and the latter with reddish-brown zig-zag lines on a pale background. *Vepricardium multispinosum* (Fig. 6) is found in sandy beaches and sub-tidal areas in the Indo-West Pacific. It is uncommon in NSW, occurring south to about Sydney, and in the Shelly Beach survey was represented by a single worn shell. *Scutus antipodes* (Fig. 7) is a striking-looking animal with a large jet-black body and a rectangular white shell partly hidden under mantle folds. It is common on rocky shores of southern Australia and New Zealand, hiding under rocks by day and emerging at night to feed on algae. *Turbo torquatus* (Fig. 8) is one of the largest gastropods occurring at Shelly Beach, with a shell size of up to 110 mm. It is an Australian endemic with two disjunct populations, one

Fig. 5. *Bassina pachyphylla* (left) and *Glycymeris grayana* (right).

Fig. 6. *Vepricardium multispinosum.*

Fig. 7. *Scutus antipodes.*

in NSW south to Green Cape and one from eastern South Australia to Western Australia. Quaternary fossils from Victoria indicate that it had a continuous range around southern Australia in the recent geological past. *Bankivia fasciata* (Fig. 9), another Australian endemic, lives in subtidal sands on ocean beaches from south-east Queensland to Tasmania and South Australia and has a wide variation in shell colour and pattern. *Nerita atrementosa* (Fig. 10) (found in Australia, New Zealand and the Ker-

Fig. 8. *Turbo torquatus* with operculum.

Fig. 9. *Bankivia fasciata*.

madec Islands) and *Bembicium nanum* (Fig. 11) (endemic) are part of a suite of algal-grazing gastropod species common in the intertidal zone of rocky shores in south-eastern Australia. *Cypraea erosa* (Fig. 12) is a widespread Indo-West Pacific cowrie found from east Africa to Hawaii and it is the most southerly occurring of the tropical cowries in eastern Australia, occurring as far south as Eden. It has a distinctive thickened rim marked with vertical streaks. *Cymatium parthenopeum* (Fig. 13) is widely distributed in subtropical and warm temperate seas of both hemispheres and in Australia is found in temperate waters from the NSW north coast to south-west Western Australia. Live animals have a hairy periostracum and prey on bivalves including oysters. *Opalia australis* (Fig. 14), another endemic, lives amongst anemones in the intertidal and shallow subtidal areas of rocky shores of southern Australia, from the NSW north coast to south-west Western Australia. The carnivorous volutes *Amoria undulata* and *Amoria zebra* (Fig. 15) (both endemic) live in intertidal and sub-tidal sandy habitats. *Amoria undulata* is a temperate southern species, with a discontinuous distribution from southern Queensland to Western Australia while *A. zebra* is an eastern overlap zone species, found from north Queensland south to about Sydney. *Amoria zebra* shells were commonly found in death assemblages at Shelly Beach while *A. undulata* was scarce. *Hydatina physis* (front cover) is found throughout the tropics

Fig. 10. *Nerita atrementosa*.

Fig. 11. *Bembicium nanum.*

Fig. 12. *Cypraea erosa.*

Fig. 13. *Cymatium parthenopeum.*

including northern Australia. Live specimens were most commonly seen sub-tidally at Shelly Beach. The thin fragile shell is too small to contain the fleshy body. *Umbraculum umbraculum* (Fig. 16) is an unusual-looking animal with a body covered in large pustules and topped by a saucer-shaped shell. It is widespread in the Indo-West Pacific region, extending into southern Australian waters. *Dolabrifera brazieri* (Fig. 17) is another unusual-looking animal, covered in large soft tubercles. It is a species of sea hare found in south-eastern Australia and New Zealand and grazes on algal films on rocks. *Dendrodoris nigra* (Fig. 18) is usually black or dark grey in colour and is widespread in the Indo-West Pacific, extending south to about Sydney on the Australian east coast. It can be common in the intertidal zone where it feeds on sponges. *Rostanga arbutus* (Fig. 19), an eastern overlap zone endemic, is another sponge-feeding nudi-

Fig. 14. *Opalia australis*.

Fig. 15. *Amoria undulata* (damaged shell, left) and *Amoria zebra* (right).

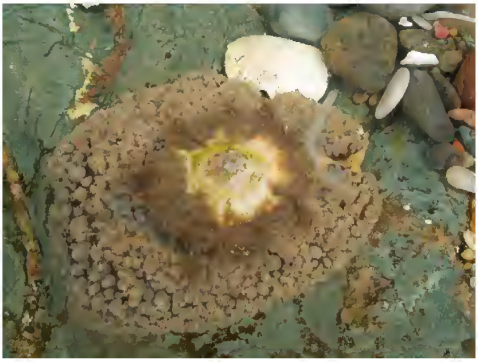

Fig. 16. *Umbraculum umbraculum.*

Fig. 17. *Dolabrifera brazieri.*

Fig. 18. *Dendrodoris nigra.*

Fig. 19. *Rostanga arbutus.*

branch. It favours red and orange sponges and appears to retain the sponge colour pigments in its skin, providing the animal with cryptic colouration while it feeds.

Conclusion

Marine bivalves and gastropods are an important part of near-coastal marine ecosystems and can be a useful indicator for total macro-invertebrate species diversity on rocky intertidal shores (Smith 2005). This study provides an example illustrating the significant diversity and biogeographical interest of the near-coastal marine bivalve and gastropod fauna of the NSW north coast.

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Appendix 1. Shelly Beach field survey dates.

Spring	Summer	Autumn	Winter
4, 5 Sep 2010	20 Dec 2009 29 Jan–2 Feb 2011 30 Jan–4 Feb 2013 18 Feb 2014 5, 8 Feb 2015	19 May 2011	6, 7 Jul 2010 30 Jun–1 Jul 2012 21 Jul 2014

Stone structures as potential aggregation sites for coccinellids in managed landscapes

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Abstract
Ladybird beetles (Coleoptera: Coccinellidae) are predators of aphid and psyllid species and are often released or encouraged into timber plantations as natural enemies of economic pests. Some temperate coccinellid species overwinter in mass aggregations; however, little is known about coccinellid aggregations in Australia. Aggregations of *Harmonia conformis* were observed only on stone walls of a camp shelter near Shelley, Victoria in July 2014. Publication of more observational records and dedicated surveys will determine if old stone walls and buildings in managed landscapes have the potential to provide overwintering habitat for natural enemies and other beneficial insects. (*The Victorian Naturalist* **132** (3) 2015, 86–88)

Keywords: overwintering; biological control; drystone wall; ladybird beetle

Introduction
The Common Spotted Ladybird Beetle, *Harmonia conformis* (Boisduval, 1835), is found throughout eastern Australia, particularly the south-east mainland and Tasmania. It was introduced to Western Australia between 1896 and 1902, in two separate introductions from New South Wales and Tasmania, as a biological control agent for aphid pests (Waterhouse and Sands 2001). The beetle has been recorded occurring naturally and released as a biological control agent of economic pests in *Eucalyptus* and *Pinus* plantations in south-eastern Australia (Carver and Kent 2000; Baker *et al.* 2003; Nahrung 2004).

Some temperate ladybird beetle species form mass aggregations when environmental conditions are unfavourable, such as during winter when temperatures drop and prey is scarce (Hagen 1962; Hodek 1967; Anderson and Richards 1977). There is limited information available on aggregation in Australian coccinellids, but *H. conformis* has been observed in mass aggregations in natural habitats in south-eastern Australia (Anderson and Richards 1977). Site choice in aggregating coccinellids is not completely understood, but it is believed the beetles use visual contrast to aim for prominent structures in the landscape, often at higher elevations (Anderson and Richards 1977; Schaefer 2004; Nalepa *et al.* 2005). Once a suitable site is located, the beetles may return there every year (Anderson and Richards 1977; Nalepa *et al.* 2000; Schaefer 2004).

Details and significance of observation
A hibernating aggregation of *H. conformis* was observed at Lawrence Lookout (36° 10' 01.3" S, 147° 34' 53.1" E, approximately 818 m ASL), near Shelley in north-east Victoria on 20 July 2014. Lawrence's lookout is located within a remnant area (approximately 20 ha) of partly cleared montane forest and is completely surrounded by managed pine plantations. Thousands of beetles were found in multiple aggregations on a camp shelter located in the centre of a small clearing at the peak of the lookout (Fig. 1). The shelter was aligned with its longest walls facing north-west and south-east. The north-west wall was constructed entirely of wood and the south-east face was open for entry to the shelter. The shorter walls facing south-west and north-east were made entirely of stone and included a stone chimney extension on both walls.

Beetles were aggregated on all the south-facing exterior stone surfaces and on interior wooden beams attached to a stone surface (Fig. 2). No beetles were found on the north-west facing wall, which was constructed of wood. Beetles in large aggregations were predominantly quiescent, but a few individuals in very small aggregations (5–10 individuals) were noticed moving very slowly within the aggregation. A toilet building constructed entirely of wood was located approximately 60 metres

Fig. 1. Photograph of the camp shelter at Lawrence Lookout, Victoria.

to the north-east of the stone camp shelter, and no beetles were found anywhere on this building. No other structures were located in the clearing. The surrounding landscape comprises predominantly managed *Pinus* plantations, and there are no other built structures within at least 2 km of the lookout. Natural granite outcrops are common in nearby natural forests (e.g. Mt Lawson State Park, Burrowa-Pine Mountain National Park).

It is not known whether this location is an annual aggregation site for *H. conformis*, nor if the population has grown from an organised release into nearby pine plantations. However, Carver and Kent (2000) record *H. conformis* as a predator of an exotic pest (the Monterey pine aphid) found in pine plantations near Shelley; they also note that *H. conformis* was observed swarming at nearby towns Bright and Myrtleford in May 1999.

Records for *H. conformis* aggregation sites are limited. Most of the Australian aggregations reported by Anderson and Richards (1977) were found on natural substrates (e.g. bark or seed pods); only one was found in a built structure (a dairy shed in northern Tasmania). However, observations of similar species in the northern hemisphere are often found in built structures (Nalepa *et al.* 2005; Raak-van den Berg *et al.* 2012). Crevices and undersides of

Figs. 2. Four photos of aggregations of *Harmonia conformis*.

rocks are common natural overwintering sites for these species (Nalepa *et al.* 2005; Honěk *et al.* 2007) and when aggregations are found on built structures, these are often made of stone or concrete (Schaefer 2004; Raak-van den Berg *et al.* 2012).

The natural cracks and crevices in man-made structures of stone, particularly dry-stone walls and buildings that have no mortar between individual stones, provide ideal habitat for many small vertebrates and invertebrates (e.g. see Manenti 2014). During winter, stone will retain heat longer after nightfall than wood or other plant materials, which may make stone structures ideal overwintering sites for cold-sensitive species such as invertebrates and reptiles. Stone has not been commonly used as a building material for a number of decades, so stone structures in managed landscapes also have great historical and cultural value. Thus, maintaining stone walls and structures in managed production landscapes has conservation potential for heritage and biodiversity. In particular, these structures can provide overwintering shelter and nesting sites for beneficial insect species, such as pollinators and natural enemies of pests, especially at higher altitudes or in temperate regions. Publication of more observational records and natural history surveys of these structural habitats will provide valuable information for ecologists and land managers.

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The diet of a Masked Owl from a sub-alpine roost

On 17 June 2014 a Masked Owl *Tyto novaehollandiae* roost was discovered within a partially dead Mountain Gum *Eucalyptus dalrympleana* at approximately 1400 m above sea level at Rocky Plains Creek, Alpine National Park, Victoria. The habitat comprises a mosaic of sub-alpine and montane vegetation communities including woodlands, heathlands, grasslands and peatlands. The dominant eucalypts include Mountain Gum, Candlebark *E. rubida* and Black Sallee *E. stellulata*.

The entire trunk of the roost tree was hollow (Fig 1.) and a fire-scar at the base of the trunk had burnt through, exposing visible owl regurgitated pellets, prey items and feathers on the ground. The Masked Owl identity was based upon several feathers. Skeletal remains of 41 mammalian prey items were identified and in-

Fig. 1. The Masked Owl roost tree at Rocky Plains being inspected by students from Federation Training.

cluded 23 Bush Rat *Rattus fuscipes*, nine Broad-toothed Rat *Mastacomys fuscus* and nine Agile Antechinus *Antechinus agilis*.

This is the first Masked Owl dietary study reporting from sub-alpine habitat on mainland Australia, and concurs with other studies in being dominated by terrestrial mammals (Debus 1993; Peake *et al.* 1993; Mooney 1993; Kavanagh 1996; McNabb *et al.* 2003; Bilney and L'Hotellier 2013). Of particular note, the Broad-toothed Rat was an important dietary item, a prey species not previously detected from contemporary dietary studies on mainland Australia. The Sub-alpine Wet Heathland at the site provides important habitat for the Broad-toothed Rat, and signs of their presence were readily observed (runs, tunnels, scats: Roger Bilney pers. obs.) suggesting they were common at the site. Of concern is that this habitat is being significantly impacted upon by Feral Horses *Equus caballus* at the site (Tolsma 2008), with a minimum of 31 individuals detected from one remote camera (Roger Bilney unpub. data).

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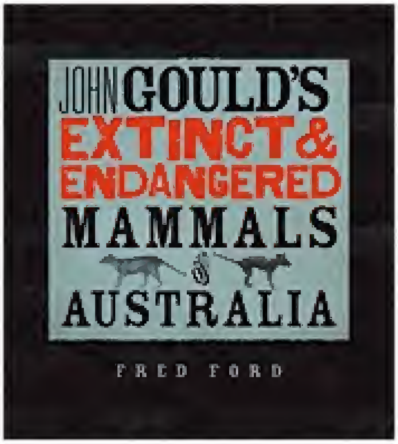
John Gould's extinct and endangered mammals of Australia

by Fred Ford

Publisher: *NLA Publishing, Canberra, 2014. 271 pages, paperback, colour illustrations, ISBN 9780642278616, RRP $49.99*



Fred Ford provides a detailed history of John Gould's career including his expeditions and interactions with a number of key players within the natural world (e.g. Charles Darwin, Richard Owen, George Bennett). Ford describes the passion and resilience shown by Gould and the number of challenges he faced, which could have discouraged a lesser adventurer. Ford describes the importance of Gould's work today with numerous accounts of researchers still using his original work as a primary resource.

Ford provides an artistic and historical account of the varying taxa originally described by Gould. These weird and wonderful creatures are either now extinct or endangered in the unique land of Australia. This book systematically lists the varying taxa from the iconic Koala and Tasmanian Devil to the lesser known Red-tailed Phascogale. Detailed descriptions of the history of the taxonomy as well as first encounters with each animal are included and provide an important background for each species.

Descriptions of the animals are accompanied by wonderful artistic interpretations of the unique animals, to provide an adequate visual representation. This book also includes reproductions of publications and media clippings referring to occurrences of species and reflecting the public's understanding of Australia's wildlife at the time. Artistic renditions from various artists of Australia's landscape, displaying typical habitats that native wildlife inhabited dating back to 1820, are also included.

This book provides a helpful and informative list of publications useful for avid naturalists to research further into this field and increase their knowledge of taxonomy for conservation purposes. This book is an important reference guide for understanding the sheer variety of mammals that once inhabited Australia as well as the steps necessary for us to take to preserve the continent's wonderful biota for the future.

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One Hundred and Four Years Ago

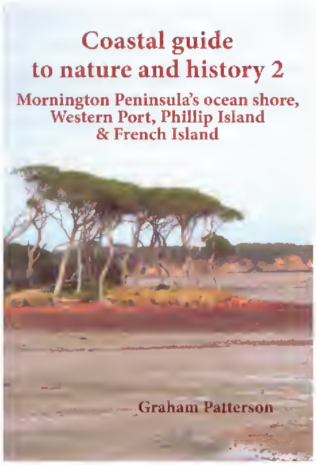
The foregoing paragraph, [regarding the extinction of the passenger pigeon] taken from the *Country-side Monthly* (England) for April, 1911, shows how great is the risk we in Australia are running of having some of our birds and mammals recorded as extinct even during the lives of the present generation. It is to be hoped that the numerous sanctuaries which have been proclaimed in Victoria will be real sanctuaries, and not merely so by proclamation.

From *The Victorian Naturalist* **XXVIII**, p. 38, June 8, 1911

Coastal guide to nature and history 2: Mornington Peninsula's ocean shore, Western Port, Phillip Island & French Island

by Graham Patterson

Publisher: *Coastal Guide Books, Briar Hill, Victoria, 2014, 168 pages, ISBN 9780992321727, RRP $29.99*



'Decades ago I set myself the challenge of walking Victoria's coastline. I have covered more than half of those 1700 kilometres but I may need another lifetime to complete the distance.' So writes Graham Patterson in the introductory section (p. 2) of this work. Although having walked (only!) half of the Victorian coastline, Graham has been generous enough to take us with him for a good 320 kilometres of it within the pages of this book.

Coastal Guide to nature and history 2 takes a sequential tour of the coast from Point Nepean eastwards to San Remo and also Phillip and French Islands, exploring the rich human, geological and natural history of this unique region. Softcover and spanning 168 pages, it consists of an introductory section covering its scope and purpose, practical advice on walking the coast including access, safety issues and tides, and Aboriginal and European settlement history. Four chapters then follow—Point Nepean to Flinders, Westernport Bay (i.e. Flinders to San Remo), Phillip Island, and French Island—which consecutively trace the coastline, highlighting important landforms and the natural and human history of each area. After this comes a general chapter on coastal animals, algae and plants (grouped largely according to habitat type), followed by sections on coastal landforms and coastal management. The layout is aesthetically appealing and richly illustrated with historical photographs and documents, topographical and natural history photographs, and Melway maps (reproduced with permission). The latter are very helpful in placing areas or landforms mentioned in the text, and, of course, with planning visits.

There is nothing that can be seriously faulted. The author has appreciated, thought about and researched what he has seen, and his experience as a teacher of general science and physics to secondary school students has enabled a skilful and clear presentation of his findings. However, in a resulting work that contains so much information in only 168 pages, further reading will invariably become necessary. To this end, there is an extensive reference list that covers nature, geology, history and coastal management. The book is also well indexed. It might have been preferable if the many beautiful photographs of plants, algae and animals all had a locality attached to their captions, but this is a minor point.

This is a book that will invite one back again and again. It succeeds in providing knowledge and appreciation of local coastal features and history, and much can be generalised to shorelines beyond its range. As I have also said about its closely allied predecessor (Patterson, 2013), this book feels good in the hand, is pleasing to the eye, and is satisfying to the mind. It is worthy to grace the bookshelf of all coast-lovers. On a more mundane point, the recommended retail price of $29.99 also does not hurt the pocket. Many congratulations Graham!

Reference

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